Bently's Corner

By Donald E. Bently

"Simple tests can show whether shaft is cracked."

Breakthroughs Made in Observing Cracked Shafts

While doing some work on the Bently Nevada Calibration Weight Balancing Routine on the ADRE® computer program, I discovered a very nice breakthrough on the observation of a cracked shaft.

Already well documented are: (1) the reduced resonance of a shaft due to lowered shaft spring rate from the crack, and (2) the tendency of the rotor system to exhibit strong 2x action in the speed range of half a resonant frequency when steady-state loaded laterally, such as with gravity. Both of these contributions are a result of work in the United Kingdom.

The observation that a cracked shaft often exhibits increasingly large erratic growth of rotative speed vibration as well as erratic phase changes is also well founded.

The new breakthrough is the very simple behavior of a shaft with a lateral crack at any place where the shaft is bent by input forces (that is, any place except at purely vertical shear spots, such as bearing supports.) **See Figure 1.**

To show this situation, suppose that you have a shaft supported between bearings with a partial crack anywhere between the span. **See Figure 2.**

Now load this shaft with a weight and observe the vertical and, especially, the horizontal deflection while rotating the shaft as shown. The typical results are shown in **Figure 3.**

The non-symmetry of the beam due to the crack, of course, causes the horizontal response to the vertical load. This simple test may be performed easily if the rotor has been removed from the machine.

Essentially, the same test may be performed on the machine by installing a trial weight of a fixed amount at a fixed radius at one place every 30 to 45 degrees successively around the rotor and by testing the response of the rotor system for each angular location of the trial weights.

The rotor system should be balanced as well as possible and any fixed slow roll should be very carefully subtracted. Good care should be taken to minimize thermal and gravity bows.

The response runs should be taken at about 40 percent of first balance resonance, using as heavy a weight as possible to get a high response, but not so heavy of a weight that much seal rubbing is incurred. Forty percent of the first resonance is used to avoid the gravity critical action at 50 percent and to be sure that the shaft is restrained almost purely by its lateral springiness. The Bode′phase results for a clockwise rotating system are shown in **Figure 4.**

The effects at 50 percent are well documented, as previously noted, but there is also very interesting undocumented behavior in the self-balance resonance region. This behavior is caused by the fact that the spring coefficient of the shaft is obviously variable with the angle of deflection, which, in turn, varies from the slow speed high spot back to 180 degrees opposite the heavy spot.

Thus, depending on the angular relationship, the rotor may "snap" through the resonance or appear well damped. In other words, the shaft exhibits apparently different amplification factors as a function of angular location of the trial weight.

While these simple tests should prove a very important addition to the technology of testing for cracked shafts, note that they are not effective if (1) the crack is at a pure shear point with no bending, and (2) the crack is symmetrical around the shaft.

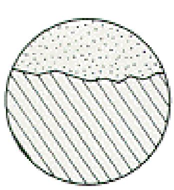

Figure 1

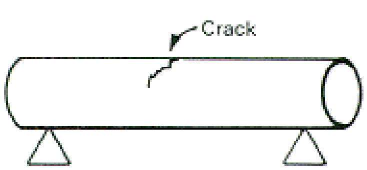

Figure 2

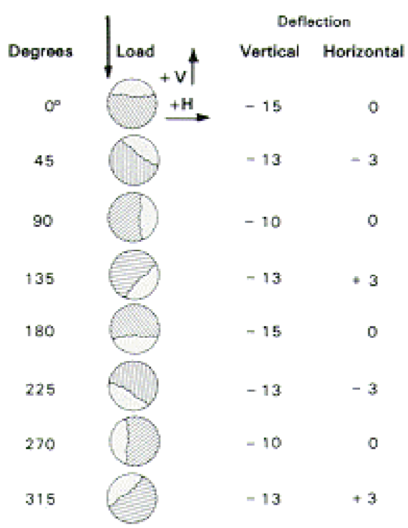

Figure 3

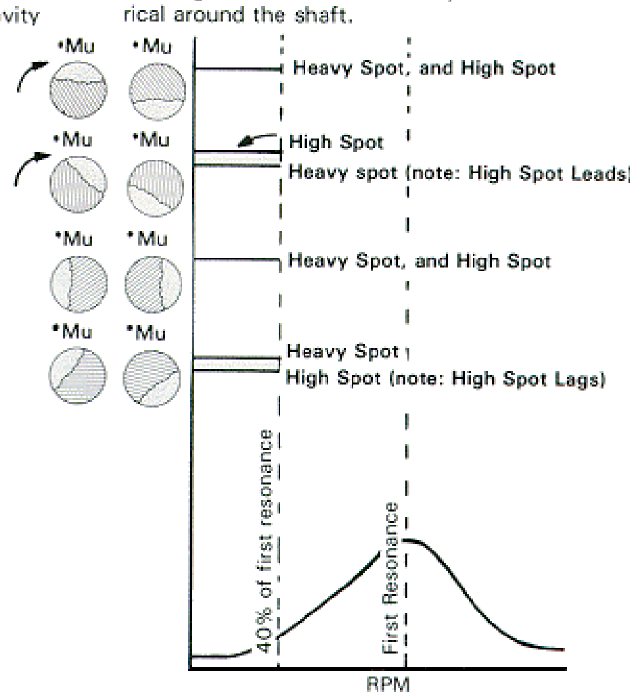

Figure 4